CLAIMS

What is claimed is:

1. A method for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum in a code division multiple access communication system, each transmitted data signal experiencing a similar channel response, the method comprising:

receiving a combined signal of the transmitted data signals over the shared spectrum;

sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

estimating a channel response for the combined signal at the multiple of the chip rate;

determining a first element of a spread data vector using the combined signal samples and the estimated channel response;

using a factor from the first element determination to determine remaining elements of the spread data vector; and

estimating data of the data signals using the determined elements of the spread data vector.

2. The method of claim 1 wherein the factor is derived using the channel response.

3. The method of claim 1 wherein the multiple of the chip rate is N-multiple of the chip rate and the factor is $\mathbf{v}^{\mathbf{H}}$ and a first element of each channel response matrix corresponding to each N-multiple of the chip rate is $h_1(0)$, $h_2(0)\ldots h_N(0)$ and

$$v^{H}=\left\{\left[h_1(0)\ ...\ h_N(0)\right]\begin{bmatrix} h_1(0) \\ \vdots \\ h_N(0)\end{bmatrix}\right\}^{-1}\left[h_1(0)\ ...\ h_N(0)\right].$$

4. The method of claim 3 wherein N is 2 and

$$v^{H}=\left\{\left[h_1(0)h_2(0)\right]\begin{bmatrix} h_1(0) \\ h_2(0)\end{bmatrix}\right\}^{-1}\left[h_1(0)h_2(0)\right].$$

5. The method of claim 3 wherein an i^{th} element of the spread data vector, $d\hat{}(i)$, other than the first element is determined per

$$d\hat{}(i)=v^{H}\left\{\begin{bmatrix} r_1(i) \\ | \\ r_N(i)\end{bmatrix}-\begin{bmatrix} h_1(i) \\ | \\ h_N(i)\end{bmatrix}\hat{d}(0)-\sum_{j=1}^{i-1}\begin{bmatrix} h_1(j) \\ | \\ h_N(j)\end{bmatrix}\cdot d(i-j-1)\right\}.$$

6. The method of claim 1 wherein the data estimating is by despreading the spread data vector.

7. The method of claim 1 wherein the factor is stored prior to the remaining elements determination.

8. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

means for receiving a combined signal of the transmitted data signals over the shared spectrum;

means for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

means for estimating a channel response for the combined signal at the multiple of the chip rate;

means for determining a first element of a spread data vector using the combined signal samples and the estimated channel response;

means for using a factor from the first element determination to determine remaining elements of the spread data vector; and

means for estimating data of the data signals using the determined elements of the spread data vector.

9. The receiver of claim 8 wherein the factor is derived using the channel response.

10. The receiver of claim 8 wherein the multiple of the chip rate is N-multiple of the chip rate and the factor is $\mathbf{v}^{\mathbf{H}}$ and a first element of each channel response matrix corresponding to each N-multiple of the chip rate is $h_1(0), h_2(0) \ldots h_N(0)$ and

$$\mathrm{v}^{\mathrm{H}} = \left\{ \left[h_1(0) \ldots h_N(0) \right] \begin{bmatrix} h_1(0) \\ \vdots \\ h_N(0) \end{bmatrix} \right\}^{-1} \left[h_1(0) \ldots h_N(0) \right].$$

11. The receiver of claim 10 wherein N is 2 and

$$\mathrm{v}^{\mathrm{H}} = \left\{ \left[h_1(0) h_2(0) \right] \begin{bmatrix} h_1(0) \\ h_2(0) \end{bmatrix} \right\}^{-1} \left[h_1(0) h_2(0) \right].$$

12. The receiver of claim 8 wherein the data estimating is by despreading the spread data vector.

13. The receiver of claim 8 wherein the factor is stored prior to the remaining elements determination.

14. The code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

an antenna for receiving a combined signal of the transmitted data signals over the shared spectrum;

a sampling device for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

a channel estimation device for estimating a channel response for the combined signal at the multiple of the chip rate; and

a single user detection device for determining a first element of a spread data vector using the combined signal samples and the estimated channel response and for using a factor from the first element determination to determine remaining elements of the spread data vector;

wherein data of the data signals is estimated from the spread data vector.

15. The receiver of claim 14 wherein the factor is derived using the channel response.

16. The receiver of claim 14 wherein the multiple of the chip rate is N-multiple of the chip rate and the factor is $\mathbf{v}^{\mathbf{H}}$ and a first element of each channel response matrix corresponding to each N-multiple of the chip rate is $h_1(0)$, $h_2(0)$ . . . $h_N(0)$ and

$$v^{H}=\left\{\left[h_1(0)\ldots h_N(0)\right]\begin{bmatrix}h_1(0)\\ \vdots \\ h_N(0)\end{bmatrix}\right\}^{-1}\left[h_1(0)\ldots h_N(0)\right].$$

17. The receiver of claim 16 wherein N is 2 and

$$v^{H}=\left\{\left[h_1(0)h_2(0)\right]\begin{bmatrix}h_1(0)\\ h_2(0)\end{bmatrix}\right\}^{-1}\left[h_1(0)h_2(0)\right].$$

18. The receiver of claim 14 wherein the data estimating is by despreading the spread data vector.

19. The receiver of claim 14 wherein the factor is stored prior to the remaining elements determination.

20. A method for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum in a code division multiple access communication system, each transmitted data signal experiencing a similar channel response, the method comprising:

receiving a combined signal of the transmitted data signals over the shared spectrum;

sampling the combined signal at a multiple of a chip rate of the data signals;

estimating a channel response for the combined signal at the multiple of the chip rate;

determining a cross correlation matrix using the estimated channel response;

selecting a subblock of the cross correlation matrix;

determining a Cholesky factor for the subblock;

extending the Cholesky factor;

determining the spread data vector using the extended Cholesky factor, a version of

the channel response and the samples;

estimating data of the data signals using the spread data vector.

21. The method of claim 20 wherein the channel response is estimated as a channel response matrix and the cross correlation matrix is the hermetian of the channel response matrix multiplied by the channel response matrix.

22. The method of claim 21 wherein the multiple is twice the chip rate sampling, the channel response matrix has even matrix samples H_1 and odd matrix samples H_2.

23. The method of claim 21 wherein the multiple is N-times the chip rate sampling, the channel response matrix has N sets of matrix samples, $H_1, H_2, \ldots H_N$.

24. The method of claim 20 wherein the subblock has 2W - 1 by 2W - 1 elements of the cross correlation matrix and W is a length of the impulse response.

25. The method of claim 20 wherein the determining the spread data vector uses forward and backward substitution.

26. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

means for receiving a combined signal of the transmitted data signals over the shared spectrum;

means for sampling the combined signal at a multiple of a chip rate of the data signals;

means for estimating a channel response for the combined signal at the multiple of the chip rate;

means for determining a cross correlation matrix using the estimated channel response;

means for selecting a subblock of the cross correlation matrix;

means for determining a Cholesky factor for the subblock;

means for extending the Cholesky factor;

means for determining the spread data vector using the extended Cholesky factor, a version of the channel response and the samples; and

means for estimating data of the data signals using the spread data vector.

27. The receiver of claim 26 wherein the channel response is estimated as a channel response matrix and the cross correlation matrix is the hermetian of the channel response matrix multiplied by the channel response matrix.

28. The receiver of claim 27 wherein the multiple is twice the chip rate sampling, the channel response matrix has even matrix samples H_1 and odd matrix samples H_2.

29. The receiver of claim 27 wherein the multiple is N-times the chip rate sampling, the channel response matrix has N sets of matrix samples, $H_1, H_2, \ldots H_N$.

30. The receiver of claim 26 wherein the subblock has 2W - 1 by 2W - 1 elements of the cross correlation matrix and W is a length of the impulse response.

31. The receiver of claim 26 wherein the determining the spread data vector uses forward and backward substitution.

32. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data

signal experiencing a similar channel response, the receiver comprising:

an antenna for receiving a combined signal of the transmitted data signals over the shared spectrum;

a sampling device for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

a channel estimation device for estimating a channel response for the combined signal at the multiple of the chip rate; and

a single user detection device for determining a cross correlation matrix using the estimated channel response, for selecting a subblock of the cross correlation matrix, for determining a Cholesky factor for the subblock, for extending the Cholesky factor and for determining the spread data vector using the extended Cholesky factor, a version of the channel response and the samples; and

wherein data of the data signals is estimated from the spread data vector.

33. The receiver of claim 32 wherein the channel response is estimated as a channel response matrix and the cross correlation matrix is the hermetian of the channel response matrix multiplied by the channel response matrix.

34. The receiver of claim 33 wherein the multiple is twice the chip rate sampling, the channel response matrix has even matrix samples H_1 and odd matrix samples H_2.

35. The receiver of claim 33 wherein the multiple is N-times the chip rate sampling, the channel response matrix has N sets of matrix samples, $H_1, H_2, \ldots H_N$.

36. The receiver of claim 32 wherein the subblock has 2W - 1 by 2W - 1 elements of the cross correlation matrix and W is a length of the impulse response.

37. The receiver of claim 32 wherein the determining the spread data vector uses forward and backward substitution.

38. A method for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum in a code division multiple access communication system, each transmitted data signal experiencing a similar channel response, the method comprising:

receiving a combined signal of the transmitted data signals over the shared spectrum;

sampling the combined signal at a multiple of a chip rate of the combined signal;

estimating a channel response for the combined signal at the multiple of the chip rate;

determining a cross correlation matrix using the estimated channel response;

determining the spread data vector using order recursions by determining a first spread data estimate using an element from the cross correlation matrix and recursively determining further estimates using additional elements of the cross correlation matrix; and

estimating data of the data signals using the spread data vector.

39. The method of claim 38 wherein the spread data estimates are determined by combining a scalar and a vector portions of the spread data estimates.

40. The method of claim 38 wherein the spread data vector determining is performed using Yule-Walker equations.

41. The method of claim 38 wherein the first spread data estimate is determined using an element of an upper left corner of the cross correlation matrix.

42. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data

signal experiencing a similar channel response, the receiver comprising:

means for receiving a combined signal of the transmitted data signals over the shared spectrum;

means for sampling the combined signal at a multiple of a chip rate of the combined signal;

means for estimating a channel response for the combined signal at the multiple of the chip rate;

means for determining a cross correlation matrix using the estimated channel response;

means for determining the spread data vector using order recursions by determining a first spread data estimate using an element from the cross correlation matrix and recursively determining further estimates using additional elements of the cross correlation matrix; and

means for estimating data of the data signals using the spread data vector.

43. The receiver of claim 42 wherein the spread data estimates are determined by combining a scalar and a vector portions of the spread data estimates.

44. The receiver of claim 42 wherein the spread data vector determining is performed using Yule-Walker equations.

45. The receiver of claim 42 wherein the first spread data estimate is determined using an element of an upper left corner of the cross correlation matrix.

46. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

an antenna for receiving a combined signal of the transmitted data signals over the

shared spectrum;

a sampling device for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

a channel estimation device for estimating a channel response for the combined signal at the multiple of the chip rate; and

a single user detection device for determining a cross correlation matrix using the estimated channel responses, for determining the spread data vector using order recursions by determining a first spread data estimate using an element from the cross correlation matrix and recursively determining further estimates using additional elements of the cross correlation matrix; and

wherein data of the data signals is estimated from the spread data vector.

47. The receiver of claim 46 wherein the spread data estimates are determined by combining a scalar and a vector portions of the spread data estimates.

48. The receiver of claim 46 wherein the spread data vector determining is performed using Yule-Walker equations.

49. The receiver of claim 46 wherein the first spread data estimate is determined using an element of an upper left corner of the cross correlation matrix.

50. A method for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum in a code division multiple access communication system, each transmitted data signal experiencing a similar channel response, the method comprising:

receiving a combined signal of the transmitted data signals over the shared spectrum;

sampling the combined signal at a multiple of a chip rate of the combined signal;

estimating a channel response for the combined signal at the multiple of the chip rate;

determining a column of a channel correlation matrix using the estimated channel response;

determining a spread data vector using the determined column, the estimated channel response, the received combined signal and a fourier transform; and

estimating data of the data signals using the spread data vector.

51. The method of claim 50 wherein the determined column is a first column of the channel correlation matrix.

52. The method of claim 50 wherein a length of an impulse response of the combined signal is W and the determined column is at least W - 1 columns from edges of the channel correlation matrix.

53. The method of claim 50 wherein the determining the spread data vector uses a fourier transform of a hermetian of a channel response matrix multiplied by the received combined signal.

54. The method of claim 50 wherein the determining the spread data vector uses a fourier transform of the determined column.

55. The method of claim 54 wherein the determined column fourier transform is multiplied by a number of spread chips transmitted in the data signals.

56. The method of claim 50 wherein the fourier transform is a fast fourier transform.

57. The method of claim 56 wherein the spread data vector determining further uses an inverse fast fourier transform.

58. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

means for receiving a combined signal of the transmitted data signals over the shared spectrum;

means for sampling the combined signal at a multiple of a chip rate of the combined signal;

means for estimating a channel response for the combined signal at the multiple of the chip rate;

means for determining a column of a channel correlation matrix using the estimated channel response;

means for determining a spread data vector using the determined column, the estimated channel response, the received combined signal and a fourier transform; and

means for estimating data of the data signals using the spread data vector.

59. The receiver of claim 58 wherein the determined column is a first column of the channel correlation matrix.

60. The receiver of claim 58 wherein a length of an impulse response of the combined signal is W and the determined column is at least W - 1 columns from edges of the channel correlation matrix.

61. The receiver of claim 58 wherein the determining the spread data vector uses a fourier transform of a hermetian of a channel response matrix multiplied by the received

combined signal.

62. The receiver of claim 58 wherein the determining the spread data vector uses a fourier transform of the determined column.

63. The receiver of claim 62 wherein the determined column fourier transform is multiplied by a number of spread chips transmitted in the data signals.

64. The receiver of claim 58 wherein the fourier transform is a fast fourier transform.

65. The receiver of claim 58 wherein the spread data vector determining further uses an inverse fast fourier transform.

66. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

an antenna for receiving a combined signal of the transmitted data signals over the shared spectrum;

a sampling device for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

a channel estimation device for estimating a channel response for the combined signal at the multiple of the chip rate; and

a single user detection device for determining a column of a channel correlation matrix using the estimated channel response, and for determining a spread data vector using the determined column, the estimated channel response, the received combined signal and a fourier transform; and

wherein data of the data signals is estimated from the spread data vector.

67. The receiver of claim 66 wherein the determined column is a first column of the channel correlation matrix.

68. The method of claim 66 wherein a length of an impulse response of the combined signal is W and the determined column is at least W - 1 columns from edges of the channel correlation matrix.

69. The receiver of claim 66 wherein the determining the spread data vector uses a fourier transform of a hermetian of a channel response matrix multiplied by the received combined signal.

70. The receiver of claim 66 wherein the determining the spread data vector uses a fourier transform of the determined column.

71. The receiver of claim 70 wherein the determined column fourier transform is multiplied by a number of spread chips transmitted in the data signals.

72. The receiver of claim 66 wherein the fourier transform is a fast fourier transform.

73. The receiver of claim 66 wherein the spread data vector determining further uses an inverse fast fourier transform.

74. A method for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum in a code division multiple access communication

system, each transmitted data signal experiencing a similar channel response, the method comprising:

receiving a combined signal of the transmitted data signals over the shared spectrum;

sampling the combined signal at a multiple of a chip rate of the data signals;

combining the multiple chip rate samples as effective chip rate samples;

estimating a channel response for the combined signal at the multiple of the chip rate;

combining the multiple chip rate estimated channel response as an effective chip rate channel response;

determining a spread data vector using the effective samples, the effective channel response and a fourier transform; and

estimating data of the data signals using the spread data vector.

75. The method of claim 74 wherein the multiple chip rate samples and the multiple chip rate estimated channel response are weighted prior to combining.

76. The method of claim 74 wherein the effective chip rate channel response is an effective channel response matrix.

77. The method of claim 74 wherein the determining of the spread data vector uses a column of a channel response matrix derived using the effective chip rate response.

78. The method of claim 74 wherein the column is a first column of the channel response matrix.

79. The method of claim 74 wherein the spread data vector determining further uses an inverse fourier transform.

80. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

means for receiving a combined signal of the transmitted data signals over the shared spectrum;

means for sampling the combined signal at a multiple of a chip rate of the data singals;

means for combining the multiple chip rate samples as effective chip rate samples;

means for estimating a channel response for the combined signal at the multiple of the chip rate;

means for combining the multiple chip rate estimated channel response as an effective chip rate channel response;

means for determining a spread data vector using the effective samples, the effective channel response and a fourier transform; and

means for estimating data of the data signals using the spread data vector.

81. The receiver of claim 80 wherein the multiple chip rate samples and the multiple chip rate estimated channel response are weighted prior to combining.

82. The receiver of claim 80 wherein the effective chip rate channel response is an effective channel response matrix.

83. The receiver of claim 80 wherein the determining of the spread data vector uses a column of a channel response matrix derived using the effective chip rate response.

84. The receiver of claim 80 wherein the column is a first column of the channel response matrix.

85. The receiver of claim 80 wherein the spread data vector determining further uses an inverse fourier transform.

86. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

an antenna for receiving a combined signal of the transmitted data signals over the shared spectrum;

a sampling device for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

a channel estimation device for estimating a channel response for the combined signal at the multiple of the chip rate; and

a single user detection device for combining the multiple chip rate samples as effective chip rate samples, for combining the multiple chip rate channel response as an effective chip rate channel response, and for determining a spread data vector using the effective samples, the effective channel response and a fourier transform; and

wherein data of the data signals is estimated from the spread data vector.

87. The receiver of claim 86 wherein the multiple chip rate samples and the multiple chip rate estimated channel response are weighted prior to combining.

88. The receiver of claim 86 wherein the effective chip rate channel response is an effective channel response matrix.

89. The receiver of claim 86 wherein the determining of the spread data vector uses a column of a channel response matrix derived using the effective chip rate response.

90. The receiver of claim 86 wherein the column is a first column of the channel response matrix.

91. The receiver of claim 86 wherein the spread data vector determining further uses an inverse fourier transform.

92. A method for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum in a code division multiple access communication system, each transmitted data signal experiencing a similar channel response, the method comprising:

receiving a combined signal of the transmitted data signals over the shared spectrum;

sampling the combined signal at a multiple of a chip rate of the data signals;

estimating a channel response as a channel response matrix for the combined signal at the multiple of the chip rate;

determining a padded version of a spread data vector of a size corresponding to the multiple chip rate using a column of the channel response matrix, the estimated channel response matrix, the samples and a fourier transform;

estimating the spread data vector by eliminating elements of the padded version so that the estimated spread data vector is of a size corresponding to the chip rate.

93. The method of claim 92 wherein the multiple of the chip rate is an N-multiple of the chip rate and the estimated spread data vector comprises elements of the padded version spaced by N elements.

94. The method of claim 93 further comprising determining an expanded version of the channel response matrix by adding N - 1 columns for every column of the channel response matrix.

95. The method of claim 92 wherein the fourier transform is a fast fourier transform.

96. The method of claim 95 wherein the padded version determining further uses an inverse fast fourier transform.

97. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

means for receiving a combined signal of the transmitted data signals over the shared spectrum;

means for sampling the combined signal at a multiple of a chip rate of the data signals;

means for estimating a channel response as a channel response matrix for the combined signal at the multiple of the chip rate;

means for determining a padded version of a spread data vector of a size corresponding to the multiple chip rate using a column of the channel response matrix, the estimated channel response matrix, the samples and a fourier transform;

means for estimating the spread data vector by eliminating elements of the padded version so that the estimated spread data vector is of a size corresponding to the chip rate.

98. The receiver of claim 97 wherein the multiple of the chip rate is an N-multiple of the chip rate and the estimated spread data vector comprises elements of the padded version spaced by N elements.

99. The receiver of claim 98 further comprising determining an expanded version of the channel response matrix by adding N - 1 columns for every column of the channel

response matrix.

100. The receiver of claim 96 wherein the fourier transform is a fast fourier transform.

101. The receiver of claim 100 wherein the padded version determining further uses an inverse fast fourier transform.

102. A code division multiple access receiver for use in receiving a plurality of data signals transmitted from a transmitter site over a shared spectrum, each transmitted data signal experiencing a similar channel response, the receiver comprising:

an antenna for receiving a combined signal of the transmitted data signals over the shared spectrum;

a sampling device for sampling the combined signal at a multiple of a chip rate of the transmitted data signals;

a channel estimation device for estimating a channel response as a channel response matrix for the combined signal at the multiple of the chip rate;

a single user detection device for determining a padded version of a spread data vector of a size corresponding to the multiple chip rate using a column of the channel response matrix, the estimated channel response matrix, the samples and a fourier transform, and for estimating the spread data vector by eliminating elements of the padded version so that the estimated spread data vector is a size corresponding to the chip rate.

103. The receiver of claim 100 wherein the multiple of the chip rate is an N-multiple of the chip rate and the estimated spread data vector comprises elements of the padded version spaced by N elements.

104. The receiver of claim 101 further comprising determining an expanded version of the channel response matrix by adding N - 1 columns for every column of the channel response matrix.

105. The receiver of claim 102 wherein the fourier transform is a fast fourier transform.

106. The receiver of claim 102 wherein the padded version determining further uses an inverse fast fourier transform.